Juggling Electrons at MAX IV

Master Thesis Popular Science Summary

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The MAX IV storage rings can circulate multiple electron packets at once, or just one. By creating a secondary orbit, both options can be combined to get the best of both worlds.

At MAX IV in Lund, electrons race around in circular accelerators known as storage rings. When the electrons are bent by magnetic fields, they emit light in a process called synchrotron radiation. In the extreme conditions of a storage ring — where trillions of electrons moving near the speed of light are focused into a beam as thin as a human hair — synchrotron radiation is used to create some of the brightest UV and X-ray sources in the world. This light is used in experiments ranging from biomedical research to nanoscience and industrial applications.

The electrons travel in packets called bunches, producing pulses of light. This project focuses on MAX IV's smaller storage ring, where up to 32 bunches can be stored at a time. Most of the time, the ring is filled with as many bunches as possible to maximize the amount of light produced. Some experiments want more time between each light pulse, which can be done by placing only a single bunch in the ring. However, this has the downside of reducing the amount of light available for the other experiments.

A proposed solution to this trade-off is called TRIBs, which stands for *Transverse Resonant Island Buckets*. In TRIBs, each bunch can be split into four groups: a core, which orbits around the ring as usual, and three islands which move around the core orbit like moons orbiting a planet. But these islands are not held together by gravity. Instead, the islands are juggled around by magnets, nudging them in just the right direction at just the right time.

So how can this complex dance of electrons be of any use? Since the islands follow a different path than the core, the experiments can choose to block out either the island light or core light. One bunch can now be placed in the island orbit, while the remaining 31 bunches stay in the core orbit. In this way, experiments can choose whether they see the light from a single bunch or multiple bunches simply by blocking the light from the core or from the islands.

One remaining issue with the island orbits is that they are sensitive to the slightest nudge, like trying to juggle in the wind. Those nudges can come from the insertion devices, which are specialized magnets in the ring designed to create high-quality synchrotron radiation for the experiments. The strength of these magnets can be adjusted to change the wavelength of the light, but doing so also moves the islands.

In this project, an analytical model is used to describe the island motion, summarizing it with just four numbers: the TRIBs parameters. Methods for measuring the TRIBs parameters are developed, and the results agree well with both theory and simulations. The model is used to find a way to cancel the movement of the islands caused by insertion devices by adjusting the strengths of magnets in the ring. This new compensation method is tested and shown to be very promising.

*MAX IV